A Study of Backside Damage Gettering in Silicon Wafer Using a Cavitating Jet(キャビテーション噴流によるシリコンウェーハのバックサイドダメージゲッタリングに関する研究)

著者	熊野 弘之
号	3100
発行年	2003
URL	http://hdl.handle.net/10097/8372

	くま の ひろ ゆき
氏 名	熊 野 弘 之
授 与 学 位	博士（工学）
学位授与年月日	平成16年3月25日
学位授与の根拠法規	学位規則第4条第1項
研究科，専攻の名称	東北大学大学院工学研究科（博士課程）機械知能工学専攻
学 位 論 文 題 目	A Study of Backside Damage Gettering in Silicon Wafer by Using a Cavitating Jet （キャビテーション噴流によるシリコンウェーハのバックサイドダメージゲッタリングに関する研究）
指 導 教 官	東北大学教授 祖山 均
論 文 審 査 委 員	主査 東北大学教授 祖山 均 東北大学教授 坂 真澄 東北大学教授 小柳 光正 東北大学教授 井小萩 利明

論 文 内 容 要 旨

Chapter 1 Introduction

The purpose of this research work is to establish a novel gettering method using a cavitating jet as the useful method which would be implemented to actual semiconductor manufacturing. Silicon wafers are inevitably contaminated with several unwanted impurities during device processing. Gettering is extremely important technique in semiconductor manufacturing to remove unwanted impurities from the surface region in a silicon wafer used for electronic device fabrication. Impurities have sufficient mobility to diffuse in silicon wafer at high temperature and adhere to crystal defects during cooling process. If crystal defects are intentionally introduced as gettering sites into certain region in a silicon wafer, unwanted impurities are gathered into the region and precipitate there. As a result, an impurity free surface region can be obtained. The proposed method is to introduce gettering sites by using the cavitating jet. Conventional gettering methods have some problems such as limited use, cost or additional contamination. The sand blast gettering method which was widely used is now rarely used because it causes additional contamination, which is more critical than effectiveness of gettering by the method. The proposed method utilizes cavitation impacts caused by the cavitating jet in order to introduce gettering sites into silicon wafers. Cavitation can produce high pressure impact to cause elastic and plastic deformation on metallic materials when cavitation bubbles collapse. If the intensity of cavitation impact is properly controlled and the cavitating jet is applied to the backside surface of silicon wafers under appropriate jet condition, the silicon wafers with backside damage as gettering sites could be obtained. The noteworthy particularity of this method is that introduction of backside damage can be achieved using water only. Introduction of the backside damage for the gettering by the cavitating jet solves the problem of additional contamination in sand blast method. The cavitating jet is able to introduce backside damage without the use of particles, and also washes the wafer at the same time. Furthermore, the method of introducing backside damage using the cavitating jet has the advantage of manufacturing simplicity with respect compared with other methods involving laser treatment, polysilicon back coating or ion implantation.

Chapter 2 Introduction of Backside Damage into Silicon Wafer by Using a Cavitating Jet

Firstly, in order to investigate suitable condition of the cavitating jet to introduce backside damage into silicon wafer, silicon wafers were treated by the cavitating jet under several jet conditions and the surface of treated wafers were observed. The condition of the cavitating jet to introduce damage into silicon wafer instead of destroying the whole wafer was revealed. The cavitating jet can introduce several types of severe cracks and light damage by controlling intensity of cavitation impact. Only light damage can be introduced without cracks, if the intensity of impact was appropriately controlled. In order to investigate that the introduced damage is effective for gettering, the surface was observed after applying thermal treatment to the wafer treated by the cavitating jet. The thermal treatment was to produce oxidation induced stacking faults (OSF). In the case of gettering method by means of backside damage such as shot blasting method, generally, it is known that OSF occurring in the region damage introduced during subsequent thermal treatment are effective gettering sites. If there are OSF in the region damage introduced after thermal treatment, it can be said that introduced damage is effective for gettering. After thermal treatment, OSF were observed on the surface of the wafers that were treated by the cavitating jet under several jet conditions. Figure 2-12 shows typical OSF on the wafer surface. OSF were not observed in the severely damaged area where cracks were introduced, but only weaker damaged area. It means that the weaker impact condition of the cavitating jet can be used to introduce suitable damage for gettering. Suitable damage for gettering introduced by the cavitating jet was found to occur when the injection pressure p and standoff distance s were 2.5MPa and 15mm, respectively. The density of OSF on the surface was increased with treating time by the cavitating jet. The pulse height distribution of impacts caused by the cavitating jet was also measured. The magnitude of impact to introduce suitable damage estimated from the measurement of impact distribution was 10~18N.

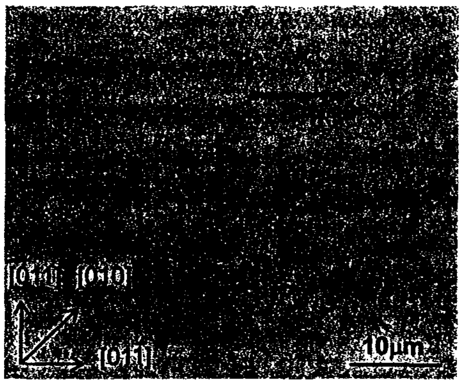
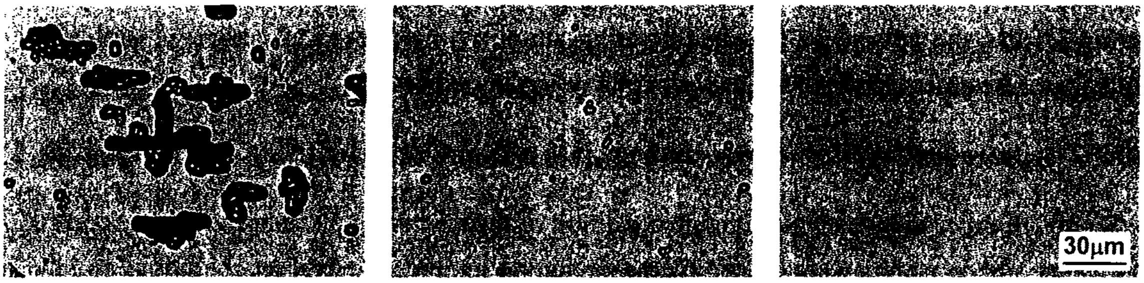


Fig. 2-12 OSF on the treated surface

Chapter 3 Evaluation of Damage in Silicon Wafer Introduced by a Cavitating Jet

In order to evaluate the effective damage for gettering which transform to OSF during thermal treatment, the surface treated by the cavitating jet was investigated. First, the surface treated by the cavitating jet under suitable jet condition was investigated by means of X-ray diffraction. Under this condition, large cracks which could be observed using optical microscope were not introduced. The distribution of X-ray diffraction from the treated surface was different from that of non-treated surface. The diffraction angles determined from the results were not significantly different. The half width of the distribution of X-ray diffraction is widened by introducing damage with the cavitating jet. It can be said that the crystal lattice of wafer surface was disturbed after treatment by the cavitating jet. The damage was



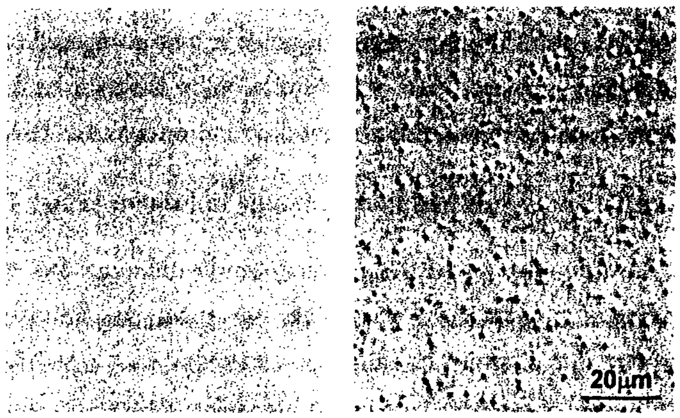
(a) p = 2.5MPa, s = 20mm (b) p = 2.5MPa, s = 15mm (c) Non-treated region

Fig. 3-10 Etched surface (Secco etching 5min)

also observed after etching to confirm the source of OSF which could not be observed without etching. In order to visualize introduced damage, the crystallographic etching which is widely used to reveal defects on the silicon surface was applied. Figure 3-10 shows the Secco etched surface. There are large and small orbiculate etch pits on the crack introduced surface as shown in Fig. 3-10 (a). The large cracks appear as array of the large etch pits. The small etch pits are observed in the area in which cracks are not observed before etching. On the other hand, there are only small etch pits on the surface treated by weak impact condition as shown in Fig. 3-10 (b). In the non-treated region of the same wafer, there are no etch pits as shown in Fig. 3-10 (c). Small etch pits show the introduced damage. Considering that OSF occur in the region where cracks are not introduced, the damage observed as small etch pits are effective for gettering which transform to OSF during thermal treatment. It is necessary for gettering to introduce only the damage observed as small etch pits without generation of debris of silicon from large cracks.

Chapter 4 Evaluation of Gettering Ability in Silicon Wafer with Backside Damage Introduced by a Cavitating Jet by Etching Method

The effectiveness of gettering by backside damage introduced with the cavitating jet was evaluated. The evaluation of gettering effectiveness was carried out based on a method involving intentional copper contamination and etching. The wafers, which had been previously treated by the cavitating jet to introduce backside damage, were intentionally contaminated and thermally treated. If the wafer had no gettering sites, contaminations precipitate in the surface region and make additional defects. After applying crystallographic etching to the wafer, the defects on the surface could be observed as etch pits. Figure 4-8 shows the etched surface of the wafer which had been partially backside damaged through intentional contamination and subsequent thermal treatment. The



(a) No etch pit in the region with backside damage (b) Etch pits in the region without backside damage

Fig. 4-8 Etch pits in the region with and without backside damage of front side surface

surface is opposite side to damage introduced side. Although the many etch pits induced on the front side surface by the contaminations were observed in the region without backside damage as shown in Fig. 4-8 (b), no etch pits were found in the front side surface region with backside damage as shown in Fig. 4-8 (a). It is demonstrated that damage introduced by the cavitating jet can getter contaminations. Namely, the damage introduced by the cavitating jet concentrated the contamination well away from any sensitive surface device area. The effectiveness of gettering by backside damage introduced with the cavitating jet has been explicitly demonstrated.

Chapter 5 Evaluation of Electrical Effectiveness of Gettering by Backside Damage in Silicon Wafer Introduced by a Cavitating Jet

The electrical effectiveness of gettering by backside damage in silicon wafer introduced with the cavitating jet was evaluated by means of photocapacitance measurement. Contaminations create deep levels between the valence band and conduction band in silicon wafer. The photocapacitance measurement is available for evaluation of the deep levels existing in silicon and the density of deep levels also can be obtained. The wafer, which had previously partly backside damage, was intentionally contaminated and submitted to a thermal treatment. For the reference, the starting material without backside damage and contamination was also measured. Schottky diodes were fabricated with titanium on the regions with and without backside damage of the wafer prepared in this way. Titanium was sputtered and patterned by wet etching. Figure 5-7 shows the deep level density. The deep level density in the region with backside damage was closer to that of starting material, although the deep level density of the region without backside damage is considerably higher than those of others. In the region with backside damage, the deep levels exist in the region without backside damage are not detected. Namely, the intentional contaminations were eliminated from the surface active device regions.

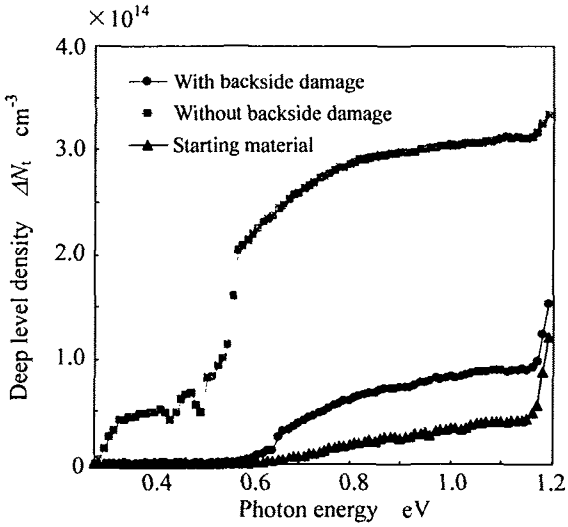


Fig. 5-7 Deep level density

Chapter 6 Conclusions

This research gives the first success in the gettering in silicon wafer by backside damage introduced by the cavitating jet. The proposed extrinsic gettering technique has a great deal of ability to be applied for actual device manufacturing since gettering effect can be achieved by only water without use of any particles. A new gettering technique which is useful for modern semiconductor device processing has been desired. The proposed technique is not only profitable for semiconductor manufacturing at present but will also become powerful tool for ensuring the reliability of semiconductor devices.

論文審査結果の要旨

半導体デバイスの製造過程でのシリコンウェーハの不可避的な汚染において，これらを素子活性領域から取り除くゲッタリング効果が発見されて以来，種々のゲッタリングが試みられてきた。しかしながらコストや煩雑性などの理由から，実際に利用できるゲッタリングは限られている。また従来用いられてきた微粒子によるシリコンウェーハへのバックサイドダメージの導入ではこの微粒子が汚染源となる可能性があり，現在ではほとんど使われなくなってきている。半導体デバイスの歩留まりを確保するためにはゲッタリングは不可欠で，そのための新たなゲッタリングが望まれてきた。

著者は，キャビテーション気泡の崩壊時に生じる衝撃力に着目し，これをキャビテーション噴流により発生させて，シリコンウェーハにバックサイドダメージを導入する新しいゲッタリングの開発に成功した。

本論文は，同開発と検証についてまとめたものであり，全編６章からなる。

第１章は序論である。

第２章では，シリコンウェーハにゲッタリングサイトとなるダメージを導入するためのキャビテーション噴流の条件を明らかにしている。これはキャビテーション噴流によりバックサイドダメージを導入する上で不可欠な成果である。

第３章では，シリコンウェーハに導入したダメージを評価している。ゲッタリングサイトとなるダメージは，ウェーハ表面の結晶構造が乱れていること，選択エッチングにより小さなエッチピットとして観察されることを見い出している。これはゲッタリングサイトとなるダメージを評価するための有益な知見である。

第４章では，意図的に汚染したシリコンウェーハを熱処理し，ウェーハ表面に発生する結晶欠陥を観察して，ゲッタリング効果を評価している。キャビテーション噴流により導入したバックサイドダメージがゲッタリング効果を有することを実証した実用上貴重な成果である。

第５章では，意図的に汚染したシリコンウェーハ上に作製したデバイスの電気的特性によりゲッタリング効果を評価し，キャビテーション噴流を用いたバックサイドダメージの導入がデバイスの特性を改善することを明らかにしている。これは実用化を狙った貴重な成果である。

第６章は結論である。

以上要するに本論文は，キャビテーション噴流を用いてシリコンウェーハにバックサイドダメージを導入する新規ゲッタリングを開発したもので，機械知能工学の発展に寄与するところが少なくない。

よって，本論文は博士（工学）の学位論文として合格と認める。